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NAVAL POSTGRADUATE SCHOOL
Monterey, California

TNT06-4 MIO San Francisco Bay, Atmospheric Effects After Action Report

by

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13. ABSTRACT

Our goal in this project was to provide field and command personnel with information on target detection capabilities (in this case a boat with suspected nuclear material) to enhance the effectiveness of marine interdiction operations, both in the planning stages and during the actual operation. We addressed both visual detection with the naked eye or binoculars and radar detection. Our focus is on how environmental factors affect the transmission of radiation in the visible and radio bands of the electromagnetic spectrum. By providing the relevant personnel with this information we hope to enhance overall situational awareness and provide an advantage over any potential adversaries who might not consider these atmospheric effects.

For this project we made *in situ* measurements of atmospheric conditions as we have in previous TNT work, but also for the first time we incorporated a large amount of "outside" information to give a better picture of the environmental conditions that affect radar and optical transmission. This information included real time observations and model predictions. Some of the models were developed by the authors and colleagues while others are available to the public on the internet or from commercial or military sources. In general, we were able to verify these models had predictive value, although there is certainly room for improvement. We incorporated a sophisticated target detection software package for the first time, although the results of this were not satisfactory for reasons we need to study further. The measurements were successful with no major problems and we were able to successfully use the TNT network to transmit data and model products among the various participants. .

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Table of Contents

EXECUTIVE SUMMARY

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We made fuller use of the TNT network system than previous projects. Although we were able to successfully transmit information using the TNT network, there were some issues regarding speed of transmission and network availability that need to be improved to make the products more useful in an actual marine interdiction situation.

I. BACKGROUND

The overall goal of our TNT studies is to develop and improve the capability to provide planners, commanders and field personnel involved in special operations and other missions with guidance on how the atmosphere affects electromagnetic (EM) propagation. This includes atmospheric effects on target detection (both radar and visible), communications systems, jamming systems and weapon performance. The idea is to make this nowcast (current conditions) and forecast (future conditions) information available within the TNT network system for quick reference by the users as a force multiplier to enhance the effectiveness and safety of special operation missions. The primary focus of our TNT06-4 effort was target detection.

The radar detection range is affected by the temperature and humidity structure of the atmosphere. When the atmosphere causes the radiation to bend back down toward the Earth's surface, a "duct" is said to occur. If both transmitter and target (or receiver) are within a duct, greatly extended ranges exist. There are two types of ducts which affect propagation between vessels: (1) a "surface duct" which is generally caused by a sharp decrease in humidity, and to a lesser degree an increase in temperature (inversion) that often occurs at the top of the atmospheric boundary layer (the turbulent part of the atmosphere that directly interacts with the surface) and (2) and an "evaporation duct" which is caused by surface evaporation. Note the evaporation duct causes ducting at the

surface but since it is distinguished from (1) due to its different effects and formation mechanisms. Quantifying the surface duct requires some type if upper air measurement using radiosondes (weather balloons) or aircraft while the evaporation duct can be estimated using measurements near the surface. Surface ducts extend several hundred meters up into the atmosphere and don't have much effect at ranges less than approximately 20 kilometers. Evaporation ducts are usually 20 meters or lower above the surface and affect ranges as close as a few hundred meters. Surface ducts typically affect all UHF, VHF and microwave frequencies while evaporation ducts only affect microwave frequencies.

Visible and infrared (electro-optical or EO) radiation and hence visible target detection ranges are affected by (1) turbulent fluctuations in temperature and humidity ("optical turbulence"), (2) suspended particles in the atmosphere ("aerosols") such as dust, sea spray and pollution, (3) cloud and fog droplets and (4) hydrometeors (rain, snow, sleet etc.). Detection of the radio (EM) and optical/IR (EO) wavelengths are also affected by a variety of non-atmospheric factors, many of which are discussed later in this report.

The authors and colleagues were involved in previous TNT exercises which resulted in improvements in our predicative capabilities and in the products available to the end users. A key part of our work involves the testing of models which are currently available to military users. The Advanced Propagation Model (APM), and its shell the Advanced Refractive Effects Prediction System (AREPS) are used to predict EM propagation in the VHF, UHF and microwave ranges. We used APM in the current and previous TNT efforts to predict radar ranges and explain anomalous communication

effects. AREPS includes the NPS evaporation duct algorithm developed by Frederickson and Davidson (2006). The Target Acquisition Weapons (TAWS) software predicts detection of various targets in the visible and infrared (IR) wavelengths. It was used for the first time in the TNT context in the effort described here. For the current effort, we also used the Naval Postgraduate School Optical Range Detection Model (NPSVIZ) developed and by authors Guest and Davidson and tuned during previous TNT efforts.

This report describes the measurements and data acquisitions that were deployed during TNT06-1 (Section II), the results of these measurements and examples of the real time and predictive products (Sections III and IV) that were that were available on the TNT network, some lessons learned (Section V), and conclusions (Section VI).

II. SCOPE OF EXPERIMENT

A. DATA COLLECTION

There were four data acquisition thrusts during TNT06-4 for our group: (1) measuring the relevant meteorological data *in situ* on the boarding vessel (Alameda County Sheriffs “Big Boat”), (2) performing target detection and visibility range estimates from the boarding vessel, (3) using publicly available meteorological data in the Bay area to provide direct mission support and for input into the various models and (4) to interview the Alameda County Sheriff deputies on the boarding vessel to determine what factors are most important to them for detection of targets and suspicious actions.

1. Surface Met System

We deployed a meteorological instrument suite on the boarding vessel which became operational at 1200 PDT on August 31, 2006 and collected data until the

end of the field program at 1415 PDT September 1, 2006. This consisted of a pole mounted in the central tower frame of the vessel with instruments attached to measure air temperature, sea surface temperature, humidity, wind vector, compass heading and GPS position (Figures 1 and 2). We used the latter two instruments to calculate ship orientation and movement which is required to get the true wind vector because the wind sensor can only measure winds relative to the ship platform. We also used an alcohol thermometer to measure sea surface temperature; this involved collecting a water sample with a small bucket and putting the thermometer into the bucket. The purpose of these measurements was (1) to determine the optical turbulence that affects visible detection and (2) to determine evaporation duct characteristics that affect radar and communications. Data were sampled every second and stored as 5 second averages. This system was similar to those in earlier TNT projects, refer to the earlier technical reports for details (brands, accuracies, etc. for the measurement system).

2. Visible Target Detection Range Estimates

This involved viewing the target vessel (Alameda County Sheriffs "Small Boat") from the boarding vessel using the naked eye, 8 power field binoculars and 6 power gyro-stabilized binoculars. We recorded the ranges when various objects (e.g. people) and features (e.g. stripes on the flag) where detectable with the various tools. We also estimated total visibility by observing shore features.

Figure 1. Photograph of the Alameda County "Big Boat", also called the "boarding vessel". The red arrow shows location of the meteorological instruments (not yet installed at time of photograph).

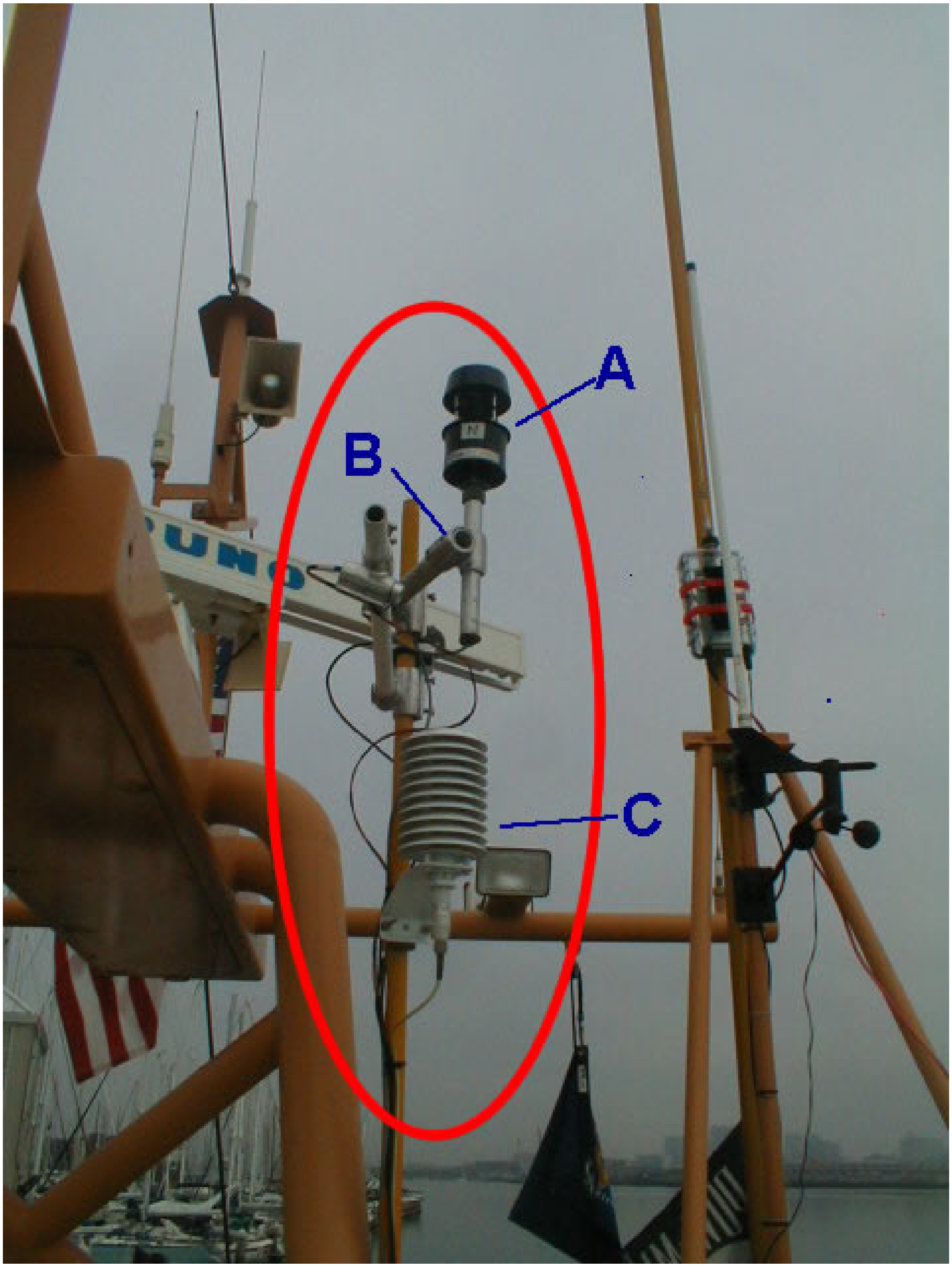

Figure 2. Close up of meteorological instruments on the boarding vessel. “A” is a sonic anemometer that measures wind speed and direction relative to the ship, “B” is an IR sensor probe that measures sea surface temperature (actual probe not visible) and “C” contains temperature and humidity sensors.

3. Publicly-Available Meteorological Data

To get a better overall picture of the atmospheric conditions that might affect interdiction operations, a variety of publicly-available products were downloaded from the web and put on the TNT Groove network. These products included:

1. Text forecasts and detailed weather discussion from the National Weather Service (NWS) for San Francisco (SF) and Oakland
2. Weather observations for various SF Bay locations in text and graphical format
3. Visibility observations from the SF and Oakland airports, updated every hour.
4. Radiosonde profiles from Oakland airport in text and graphical format, every 12 hours.
5. Map of wind speed and direction in the SF Bay area based on a model developed by Dr. Wendall Nuss, Department of Meteorology, NPS.
6. Visible and IR satellite images (grey shades) of the SF bay area every 30 minutes from a geostationary GOES satellite.
7. True color visible images from polar orbiting MODIS satellite, one or twice per day.

Examples of some of these products are shown in the results section below.

4. Interviews with Alameda County Sheriff deputies on the boarding vessel

While on the boarding vessel, Dr. Guest informally interviewed the boat operators (Alameda County deputies) to determine what factors are most important to them for detection of various targets and suspicious actions. They provided important feedback that will help guide our future efforts toward providing useful products for various military and law-enforcement groups in their efforts to detect threats to homeland security.

B. DATA PROCESSING AND MODELING

The data processing involved three systems on the boarding vessel, a Campbell Scientific data logger, a "data collection" laptop and a "data processing and display"

laptop. The data logger was located in a sealed box outside on the flying bridge while the laptops were inside the main bridge. The data logger queried the met tower sensors every second, converted the data from engineering to scientific units and saved 5 second interval data which were transmitted via cable to the data collection laptop. This computer then calculated 5 minute averages of the data, performing vector averages of the true wind speed and direction. These 5 minute data were then transferred to the data processing and display laptop and were used as input to the NPSVIZ visibility model. These basic meteorological data and the results from the NPSVIZ model were plotted on the display of the latter computer (see examples below). This information was also put on the TNT network via the Groove software. Because this was the only computer on the ship that was running Groove it was used by other participants to transfer data to the TNT network.

Meanwhile, at NPS, Ms. Jordan ran the AREPS rf propagation model using the latest Oakland radiosonde sounding data. She also ran the TAWS target range detection model using surface meteorological information. She downloaded a variety of meteorological information from the internet and transferred these to the TNT network using Groove.

III. RESULTS OF EXPERIEMENT

A. RESULTS INTRODUCTION

All the meteorological measurements and model runs performed well, with no serious problems. In this section we will present the results, and in particular, the products that were made available during the project. This section begins with a description of the weather conditions (fog, overcast, haze) since these had the potential to affect target detection. This is followed by a presentation of the visibility forecast results, the observed target vessel visibility (from the boarding vessel), the radar detection predictions, TNT connectivity issues and results from the discussion with the Alameda Sheriffs deputies.

B. GENERAL VISIBILITY AND METEOROLOGICAL CONDITIONS

The meteorological conditions on the day of the main experiment on 1 September, 2006 were common for the SF bay in summer, with low marine stratus in the morning and clearing conditions later in the day. When the boarding vessel left the dock at 0820 PDT, marine stratus covered the entire sky. This caused flat lighting which negatively affected target detection. High humidity and urban pollution caused haze which limited total visibility to approximately 5 nmi. When the boarding vessel reached the main operating area near Yerba Buena Island at 0900 PDT conditions were similar. Despite the haze, the target vessel was in continuous visual contact throughout the main experiment because it was always considerably closer than 5 nmi. By 1030 PDT visibility had improved to 7 nmi and the stratus was getting thinner. At this time the relative humidity dropped from 92% to 87% and the previously light southerly winds increased to 5 kts and changed to a northwesterly direction (Figure 3), marking the start

of the sea breeze influence. At 1050 PDT the stratus in the experiment area dissipated and the target vessel became illuminated by direct sunshine, which improved the ability to detect people and other features on the target vessel. Low stratus and fog, persisted over the San Francisco hills and in the central SF bay areas to the east of the Golden Gate. If the experiment had taken place 2 nmi further north, the presence of fog would have seriously impacted the detection ranges before 1200 PDT. Later in the day at 1220 PDT, the fog edge had retreated closer to the Golden Gate, but still was present in the SF Bay area just north of the city (Figure 4).

It is apparent that the location of the fog and marine stratus was a crucial factor affecting our ability to visually detect a target vessel. This was anticipated, and is the reason why more emphasis was placed on obtaining the supporting weather information during this TNT project compared to earlier projects. Although a substantial number of meteorological products were put on the TNT network in real time, just a few of those will be shown here. Contact the authors for the complete suite of products that were used or produced in real time during the experiment.

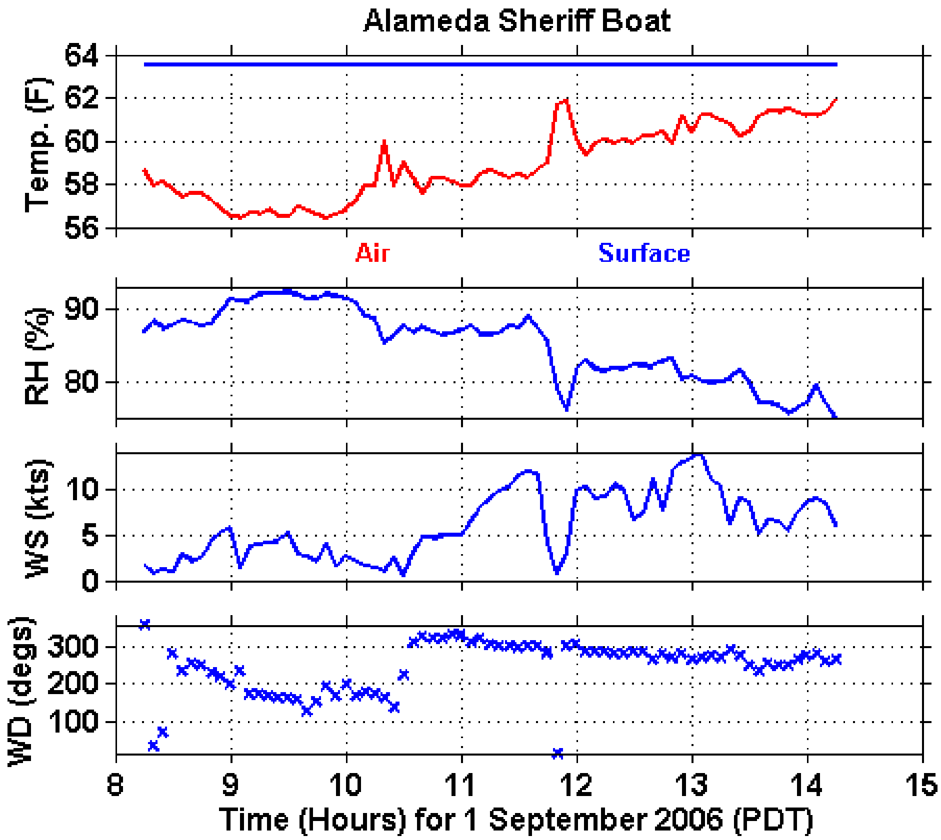

Figure 3. Meteorological conditions as measured from the boarding vessel (Temp. = Temperature, RH = Relative Humidity, WS = Wind Speed, WD = Wind Direction. The increase in temperature and decrease in RH and WS just before 1200 PDT is when the ship moved to the lee of Buena Yerba Island.

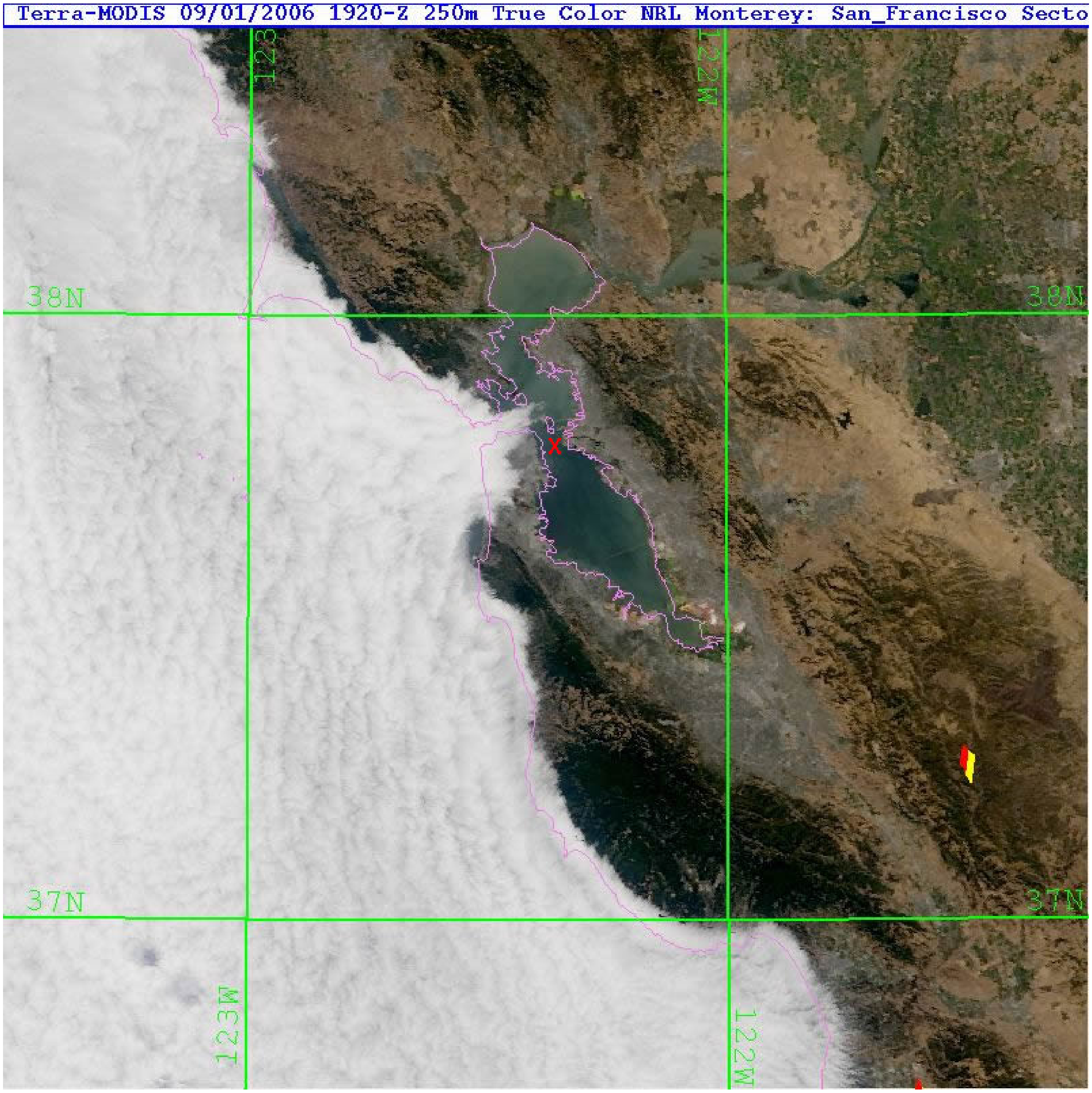

Figure 4. MODIS satellite true color image of SF Bay region at 1200 PDT, 1 September, 2006. The red "X" marks the main experiment location. Note the fog over the San Francisco hills and the "tongue" of fog projecting through the Golden Gate. At this time the experiment location was clear, but not too far from the foggy areas.

C. VISIBILITY PREDICTIONS AND OBSERVATIONS

Using the observed meteorological conditions as input, the NPSVIZ model predicted the visibility of the target boat, a person and a weapon (rifle). This information was displayed on a time series plot and put on the TNT network in real time during the main day of the experiment, September 1, 2006 (Figure 5). For the model, aerosols (haze and pollution particles) were assumed to limit visible ranges to a maximum of 5 nmi until 0930 PDT. From 0930 to 1200 PDT the maximum visibility due to the aerosol effect increased linearly to a value of 7 nmi and remained at that value for the rest of the experiment period. We can see from Figure 5 that the aerosols affected the predicted detection range of the target boat (note increase from 0930 to 1200 PDT) but not the detection of a person or weapon. This is because the latter two represented smaller targets and the ability to detect them was controlled primarily by human vision and binocular factors not atmospheric effects. The modeled effect of optical turbulence created the small variations in time; these variations are most evident in the binocular detection of a person. As expected, the optical turbulence effect was not highly significant in any of the cases. We could not verify the predicted target ship detection ranges because we were always closer than the predicted range. We were able to compare the detection range for a person and other small objects, this is discussed below.

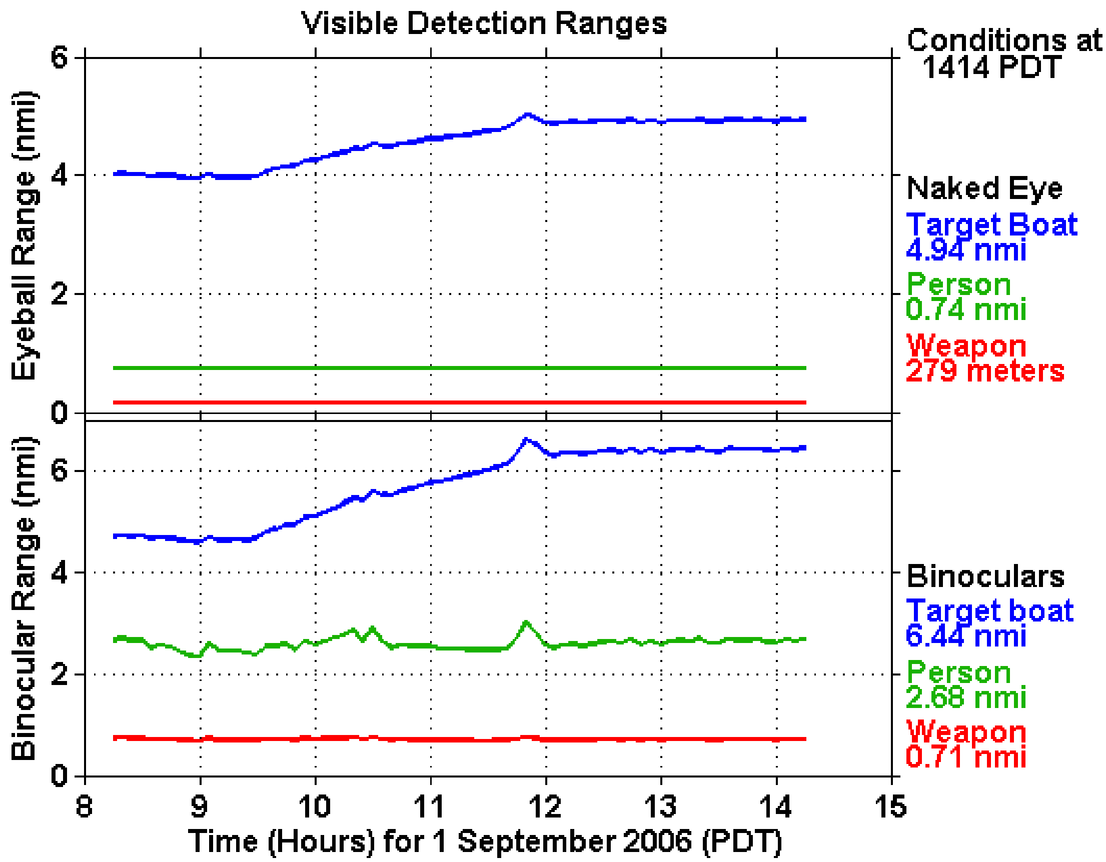

Figure 5. Time series of detection ranges for various objects based on the NPSVIZ model. Top panel represent naked eye observations (assuming 20/20 vision) while the bottom panel represent 8 power binocular observations. This was a real time product that was put on the TNT network during the experiment.

Dr. Guest, on the boarding vessel, observed various features on the target vessel using naked eyes and binoculars and at different ranges. These results are summarized in Table 1.

Table 1. Summary of Feature Observations.

Time (PDT)	Range (m)	Detection Quality	Viewing Instrument	Object	Notes
1045	2200	Good	Naked eye	Target Vessel	Overcast Sky
1045	2200	Can't detect	Naked eye	People	Overcast Sky
1045	2200	Just detectable	Naked eye	2 meter features	Overcast Sky
1045	2200	Good	Regular 8 X Binoculars	people	Overcast Sky
1045	2200	Just detectable	Regular 8 X Binoculars	0.30 meter features	Overcast Sky
1045	2200	Just detectable	Gyro-stabilized 6 X Binoculars	0.10 meter features	Overcast Sky
1056	400	Just detectable	Naked eye	People	Clear Sky Good Target Illumination
1100	2200	Just detectable	Naked eye	1 meter feature	Clear Sky
1108	1400	Just detectable	Naked eye	People	Clear Sky Bright White Background
1223	900	Can't detect	Naked eye	People	Dark Background
1245	1400	Can't detect	Naked eye	People	Dark Background
1245	1400	Can see OK	Naked eye	Flag (1 m width)	Better Contrast
1245	1400	Good	Regular 8 X Binoculars	People	Same
1245	1400	Just detectable	Regular 8 X Binoculars	10 cm stripes on flag	Much Improved When Binocs steadied
1257	460	Can see OK	Naked eye	People	Clear Sky
1257	460	Just Detectable	Naked eye	10 cm stripes	Clear Sky
1257	460	Just Detectable	Regular 8 X Binoculars	2 cm features	Clear Sky

Those data that correspond to "just detectable" in Table 1 are compared to the NPSVIZ model prediction of maximum detection range (Figure 6). We can see that the NPSVIZ model was quite accurate for some cases, but overpredicted the ranges for other cases, as seen by the points falling above the dashed (perfect match) line. The NPSVIZ model was tuned using a contrast black and white target and under good illumination conditions. When these conditions were met the model was accurate. The cases when the model overpredicted the detection range, either illumination conditions were less than ideal (it was overcast not sunny) or the background provided weak contrast.

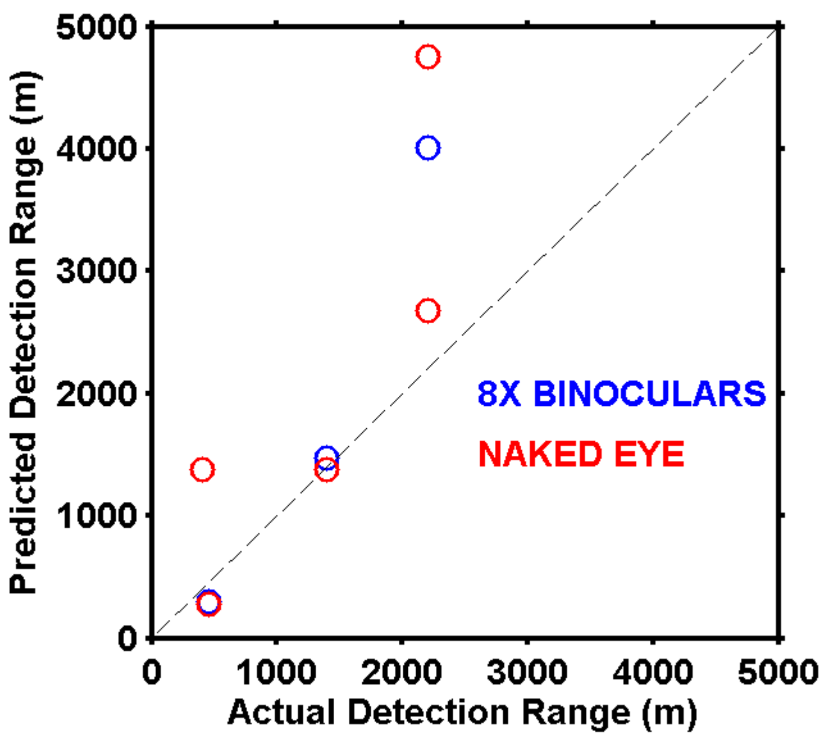

Figure 6. Comparison of predicted (NPSVIZ model) visible detection ranges with observed detection ranges for various objects. The observed ranges and type of object are from those rows in Table 1 when the object is "just detectable". The two highest points occurred during overcast conditions and with poor background contrast while contrast was poor for the point at 1400 m predicted, 450 m observed. The other points had good illumination and contrast and match the prediction quite well. Note that two points (a red and blue) are plotted in nearly the same location near the bottom left corner.

Factors other than the measured meteorological parameters affected visible detection ranges. Illumination and background contrast were important and not included in the current model. There are other factors also, such as the visual acuity of the observer and the steadiness of the observing platform. (Dr Guest has close to 20/20 vision in both eyes.) The sheriff's boat had gyro-stabilized binoculars that were used for one observation. Even though the magnification was less than the normal binoculars (6X vs 8X), the stabilized binoculars allowed considerable improvement in target resolution. As seen in Table 1, the stabilized binoculars were able to resolve objects on the target boat that were one-third the size of the smallest objects observed with normal binoculars. This shows that on a rocking boat the stabilized binoculars allow a considerable improvement in target detection capability.

This was the first TNT project where the TAWS target detection product was tested. This was originally developed by the US Air Force for aircraft detection of targets but has been modified for surface- to-surface detection, which is more relevant for surface vessels. TAWS requires a target specification, but only has a few types of vessels in its data base. Several different types of vessels were used and the results made available on the TNT network in real time. For this report we choose a "24 ft gray power boat" as the closest approximation to the target vessel. TAWS does not have a "naked eye" sensor available, we used a simulated TV camera as the detection device. The TAWs predictions were based on predicted environmental condition from a forecast made one day earlier. The TAWS predicted detection ranges were only about 0.6 nmi, with some variation due to approach angle, which was considerably less than the observed detection ranges and NPSVIZ predictions (Figure 7). It is not clear at this point

why the TAWS ranges were so small. It may due to the inputted meteorological data; more haze or fog may have been predicted. Or perhaps the specification of the viewing instrument was not accurate; the human eye may have better acuity than the TV camera assumed by TAWS. The reason for the TAWS underprediction of detection ranges needs to be investigated further.

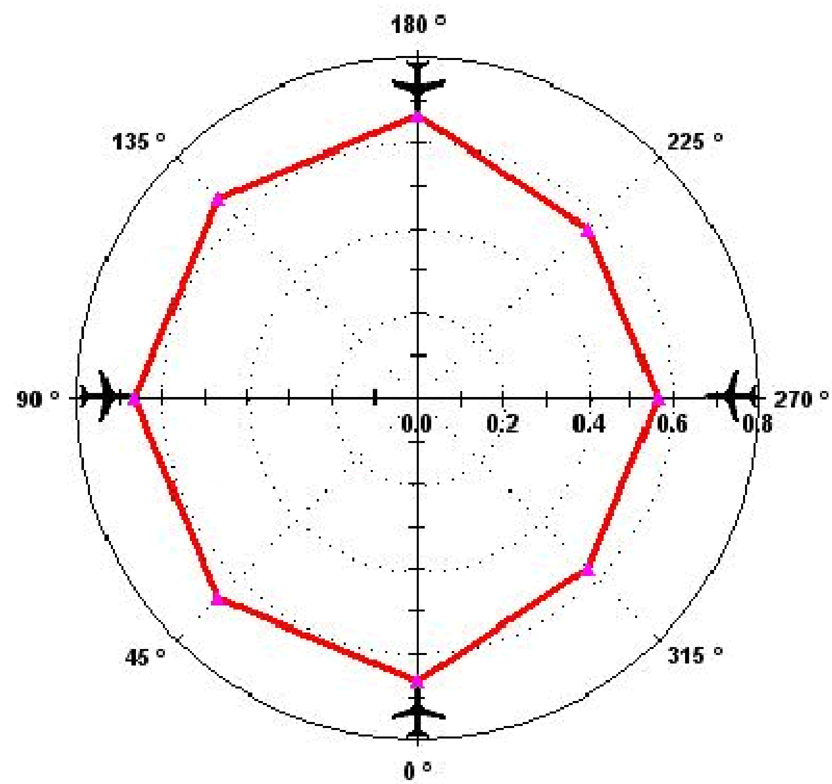

Figure 7. Visible detection ranges of the target vessel based on the TAWS model. The red line shows the predicted 75% probability of detection range for a "24 ft gray power boat" which was the closest proxy for the TNT target vessel available in the TAWS database. The background was assumed to be clear sky. The target vessel was assumed to be traveling toward the south. The different angles represent approach angles. For example, the lowest point shows the detection range when approaching from the south looking toward a target to the north. The range is a function of approach angle due to the effect of sun angle and target vessel orientation. Ranges are usually greatest with the sun behind the observer and when looking broadside to the target vessel. The dashed circular lines represent range in nautical miles as indicated by the scale. This graphic was made available on the TNT network in real time during the experiment.

D. RADAR RANGE PREDICTIONS

During this TNT experiment, the target vessel was always well within the radar range of the boarding vessel so we were not able to verify predictions of radar range. We ran the AREPS radar range prediction for the location of the boarding vessel. The output is different from what was used in previous TNT projects. In previous projects the target vessel was assumed to be in the open ocean and therefore the radar range was the same for all directions. But for the current TNT, the topography of the land around SF Bay was the dominant factor limiting radar range, therefore we used a display that shows range as a function of direction from the boarding vessel (Figure 8). At these short ranges, the atmosphere affects the radar returns, but these effects don't change the topographically-controlled maximum detection ranges. Note how the radar is unable to see objects behind islands and other topographic features, but as long as there is an unobstructed path, the radar will detect the target vessel within the bay.

We were interested in simulating an alternative scenario where a target vessel is approaching from well outside the Golden Gate. In this case, the atmosphere would have had a significant effect on maximum detection ranges. The nearest source of upper-air information needed to predict radar ranges were from the radiosonde sounding performed at the Oakland airport at 0500 PDT on September 1st (Figure 9). The modified refractive index, M, (top left panel in Figure 9) shows how the atmosphere bends radiation, which affects radar ranges. When the M profile slopes to the right going up at an angle of approximately 45 degrees in this particular figure, conditions are normal or standard. . When the line becomes more vertical, ranges are extended. If M decreases

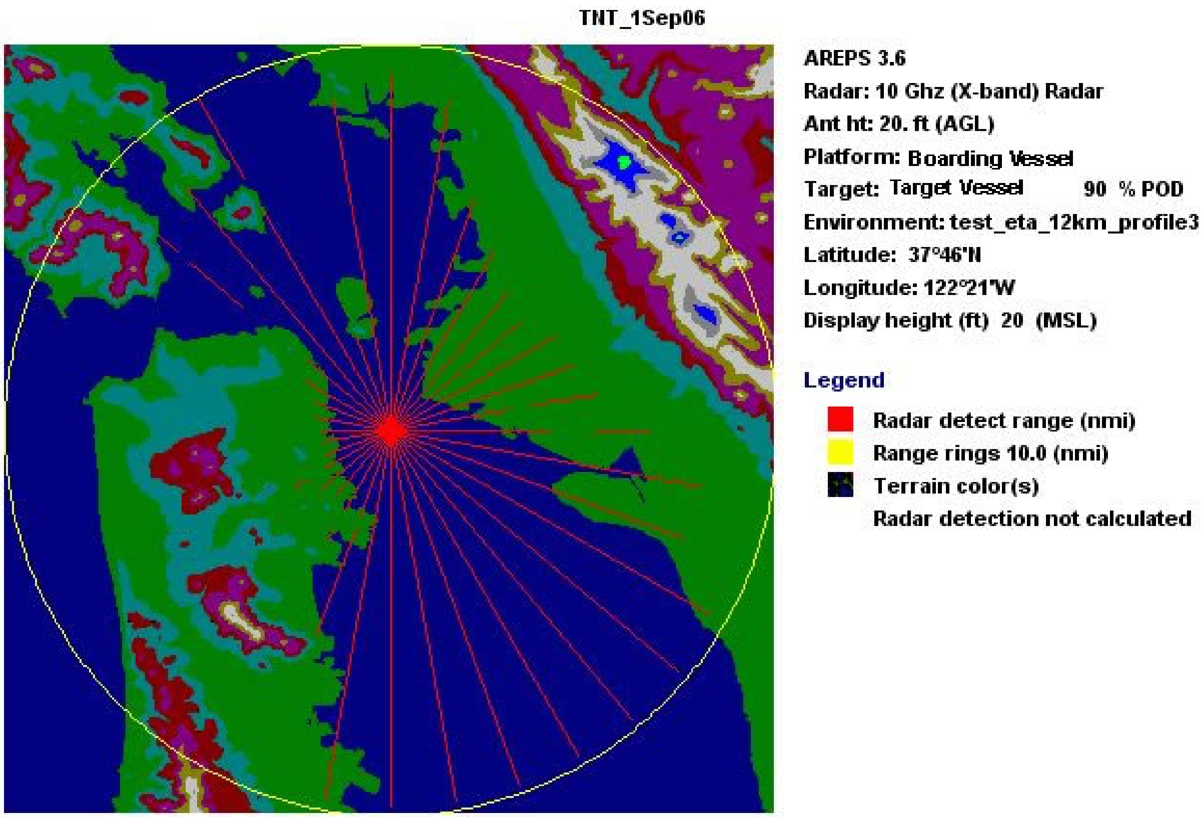

Figure 8. AREPS predictions of radar range for a 10 GHz Radar on a 20 ft antenna. The diagram is centered on the general location of the boarding vessel during the experiment. The red "spokes" represent the radar coverage regions at different angles from the boarding vessel. The topography (indicated by various colors of the land) was the primary factor controlling the range. The yellow circle represents a range of 10 nmi; the prediction display does not extend past this range, although actual and predicted ranges went past 10 nmi in the unobstructed angles.

with height, i.e. the line slopes to the left, trapping conditions exist and ranges are greatly extended. We see from the M profile that on September 1, 2006, surface trapping conditions were not present, but radar ranges would have been extended from standard conditions. This is most evident in the 300 m to 600 m elevation range where the M values don't change much with height. This region had an increase in temperature and decrease in humidity associated with the inversion that capped the marine boundary layer.

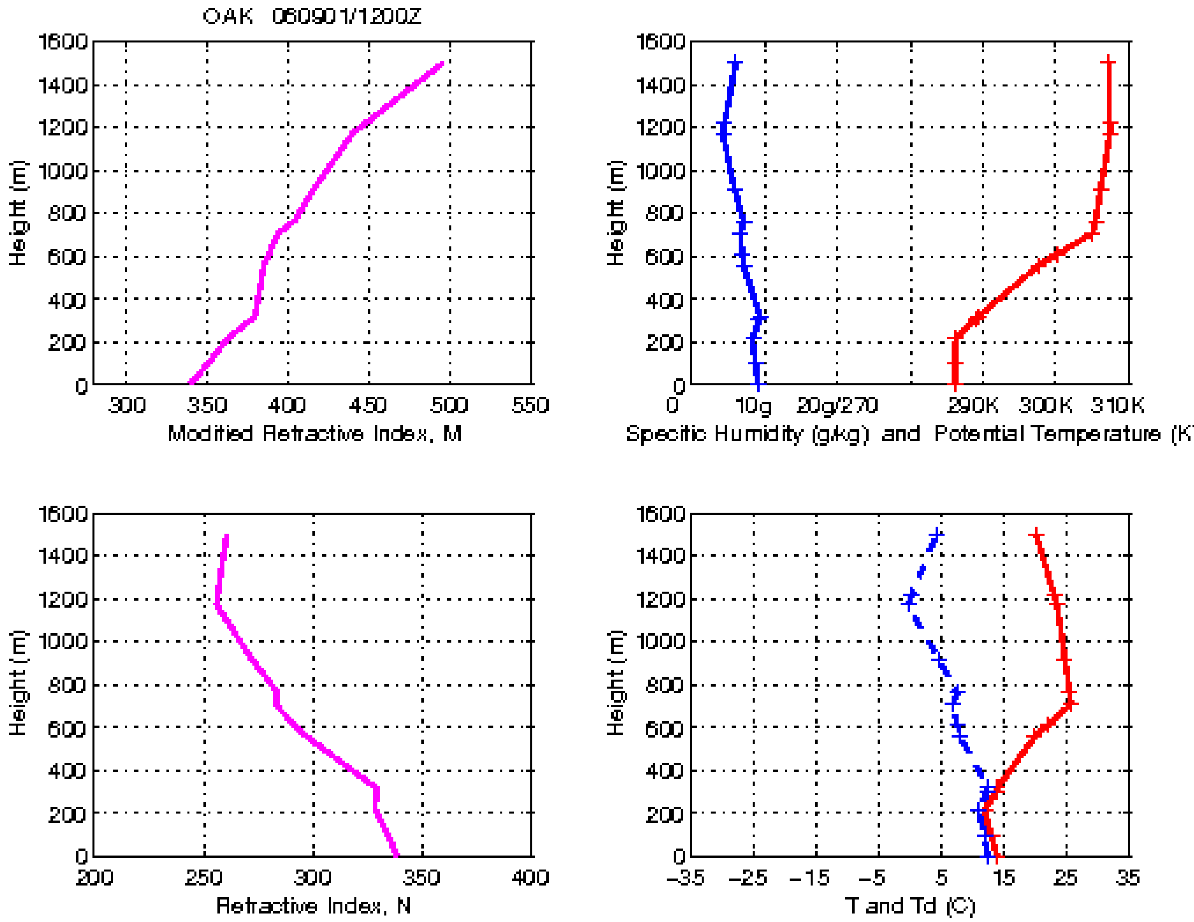

Figure 9. Profiles of atmospheric and refraction parameters from the 0500 PDT 1 September Oakland radiosonde. This plot was available in real time on the TNT network.

In the open ocean scenario, ranges for most radars would also have been affected by an evaporation duct, but the Oakland radiosonde could not possibly detect this feature.

E. TNT NETWORKING

A primary goal of our effort was to test and demonstrate the ability of using the TNT networked system to relay atmospheric information between command centers, model prediction centers and field personnel. In order to best characterize the environmental aspect of situational awareness, information sources must include local *in*

situ measurements and observations by field personnel as well as the rich variety of products available from "outside sources." These outside sources include the National Weather Service, Fleet Numerical Meteorology and Oceanography Center, the Air Force Weather Agency, other government agencies, academic institutions and commercial research and media companies. These sources provide two types of products, current observations and model predictions of future conditions. In some cases the outside products are improved by information from the inside. For example an *in situ* measurement system on an interdiction vessel could be used as input into a prediction model that exists outside of the immediate networked system and the results then fed back into the field on a timely basis. This type of procedure is already used by US military forces for many weather-related products. However it has not been fully implemented in the TNT context.

For the current experiment, we developed tools and processes for prediction of target detection characteristics using both inside (*in situ*) and outside sources of information. One of the challenges for TNT was to refine and process this enormous amount of information in a way that provides the end user on the ground or in a control center with a product that provides just the necessary information that is required without extraneous detail. A good way to accomplish this challenge is to make use of internet or siprnet infrastructure and protocols that present the end user with a user-friendly interface that has information displayed in a consistent and clear format. Hyper-links from a home page allow the user to choose those paths that he or she needs to access.

The authors created such an interface to address the target range prediction issues for TNT. However, we were not able or did not know how to incorporate this interface

into the TNT network. The problem is that the TNT network is a closed secure information network system and is not intended to have considerable interaction with outside cyberspace. The Groove software that was used during this TNT does not appear (at least to the authors) to be able to support the internet type web page interface that was originally envisioned.

We were able to use the Groove software and the TNT network system to provide a variety of products and transmit information both ways to and from the field and to NPS and all the other locations served by the TNT network. These products were organized in a simple file hierarchy. This worked satisfactorily, but was not felt to be as effective as a web type (hyperlinked) interface.

A problem with the TNT network system with respect to our operations was that the TNT network only became operational when the vessel was in the main operations region near Yerba Bueno Island (YBI), where a network antenna was located. Therefore none of the outside observations and model predictions were available through the TNT network until the main operations had already started. In a more ideal situation, information would be available for planning purposes several hours before the start of the operation.

When the ship was within range of the YBI antenna, we were able to transmit information to and from the ship using the Groove software and the TNT network system. However there were some problems. Initially we had some difficulties related to Groove access permissions. There were times when the network did not function well and we were unable to exchange information. A few times this was due to losing the radio connection from the ship to YBI, but more often it appeared to be other causes that

may have been related to the Groove software or other aspects of the TNT network. It was beyond the author's capability to diagnose many of the network issues. Even when the system was apparently up and running the data transfer rates were very slow. It took over two hours to transmit approximately 2 Mb of data, text, images and figures. Another complication was that on the main day of the project, our group had the only laptop on the boarding vessel that had TNT connectivity using Groove and so some of the other participants had to use this computer to transmit their data onto the network. This did not significantly impact our operations (we had another laptop devoted to the *in situ* measurements) and we were pleased to help out, but it did cause some delays by the other users as they had to use an unfamiliar system.

We also had some difficulties getting the outside information onto the TNT network. The plan was to have Ms. Jordan enter the supporting outside atmospheric information into the network via the computer below the main display in TOC room in Root Hall at NPS. The problem was that there were other users of this computer and there was not a clear protocol on who should get access and when.

To conclude our discussion of network issues, we demonstrated in this field program that a variety of products could be transmitted throughout the TNT network and made available to distant command and planning centers as well as the people in the field. However there are many ways this process could be made more efficient and useful.

F. RESULTS OF INTERVIEWS WITH ALAMEDA COUNTY SHERIFF DEPUTIES

The field program gave Dr. Guest the opportunity to discuss target detection issues with the operators of the boarding vessel, who were Alameda County Sheriff

deputies. Although the authors have considerable knowledge and experience with issues related to target detection, it is always enlightening to get feedback from the people who are involved in detecting various targets on an every-day basis.

The primary duty of these particular deputies is providing homeland security to the SF bay region. They are not usually involved in traditional law enforcement operations, but rather spend most of their efforts looking for behaviors and vessel movements that might involve terrorist acts or the transport of weapons and other agents of destruction. They are therefore keenly aware of issues related to visibility and radar detection.

Concerning visibility, the Sheriffs mentioned the obvious effects of fog and haze that are common in the SF Bay. They discussed how fog would often be present over land but not over the bay. Also, they were familiar with certain other fog patterns such as how it would often penetrate into the bay from through the Golden Gate so that the foggiest areas were just north of San Francisco. They discussed the importance of haze on longer range visibility, confirming the importance of the atmospheric aerosol. They have not observed the flickering effects that would be associated with optical turbulence, which is in line with our model results. This is in contrast to land locations, especially desert regions, where optical turbulence often has strong effects, even at relatively short ranges.

Similar to our observations, they noted that target illumination and background (contrast) are crucial factors affecting visible target detection. They also noted differences in target detection capabilities among different people due to varying eyesight quality and experience.

Concerning radar, they noted that conditions changed from day to day, but did not relate this to atmospheric effects. They could not associate changes in radar characteristics to specific weather conditions. This may be due, at least in part, to the short ranges encountered within the bay, as discussed earlier. The most important reason for changes in radar detection cited by the ship's skipper was that "so-and-so must have changed the settings on the radar. I get it working just right and then he fiddles with the controls and messes things up." So we can see that human issues are important factors related to the effectiveness of radar, something that may be overlooked by environmental scientists.

It may be that environmental issues are involved in this type of human issue. For example if there is a strong evaporation duct, radar clutter will be an issue and the operator may turn down the sensitivity. A few hours later or the next day, the evaporation duct may be weaker, clutter is less of an issue and optimum performance would be with a higher sensitivity setting. A different operator at this time would blame the previous operator for turning down the sensitivity too much.

IV. LESSONS LEARNED

When we deployed the surface met sensors on the boarding vessel, we initially put them in the path of the rotating radar antenna. The skipper assured us that the radar would not be used and that this location was OK. This was a mistake because one of the crew members was unaware of this, and turned on the radar. This caused it to hit one of our sensors. It seemed to continue to work OK, but on closer examination we decided that the instrument was slightly bent and probably unusable for future operations. In hindsight this was a poor choice for location of the sensors. Not only were they

susceptible to damage, this location meant the radar could not be used to determine ranges, which was an important component of our program.

We need to examine and improve the network issues for future operations. In the past we have provided most of our information outside of the TNT network using the internet and this seems to be the most efficient method, at least up to now. However, our goal is to fully incorporate target detection information in support of special operations and homeland security missions into a closed system such as the TNT network in a way that provides the end users with the information they need in a clear concise format. We hope to work the TNT group to make further progress toward these goals.

V. CONCLUSIONS

We considered this experiment to be a successful and worthwhile exercise. We were able to perform *in situ* observations and demonstrated the ability to process and bring environmental information to the field in order to help the planning and operations phase of a marine interdiction simulation. Several new products were introduced that had not been used in our previous TNT efforts, including an areal coverage diagram of radar ranges using the AREPS program, testing of a new target detection software package (TAWS) and fully incorporating our data transmission and product displays into the TNT network. The foggy and hazy conditions that were present in the SF Bay presented environmental conditions and resulting effects on target detection that increased our knowledge and ability to account for these effects and will result in improved forecast and nowcast models. We also gained more of an appreciation and understanding of how non-atmospheric factors such as human, platform and viewing instrument characteristics affects target detection. There are areas that need more work, in particular improving the

performance of TAWS and finding better ways to network our data streams and target detection products. We hope to be able to continue our work in future TNT events.

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